FISHERY RESEARCH

JOB PERFORMANCE REPORT

Grant F-73-R-20

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Job Performance Report

July 1, 1997 to June 30, 1998

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Project 8—Hatchery Trout Evaluations
Subproject 1: Fingerling and Catchable Evaluations
Subproject 2: Sterile Trout Investigations

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JOB PERFORMANCE REPORT
SUBPROJECT #1: FINGERLING AND CATCHABLE EVALUATIONS

State of: Idaho | Grant No.: F-73-R-20, Fishery Research

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Subproject #1: Fingerling and Catchable Evaluations

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ABSTRACT

We continued put-and-grow stocking evaluations in lakes and reservoirs during 1997 to compare returns and cost to the creel for fingerling and catchable rainbow trout *Oncorhynchus mykiss*. Since 1992, the study has included 72 evaluations in 20 lakes and reservoirs statewide. All waters were stocked with both fingerling and catchable rainbow trout. We used creel surveys to estimate percent return and cost per fish creeled.

To date, spring fingerlings have been the most cost-efficient plant at $2.05 per fish creeled, followed by catchables ($2.61) and fall fingerlings ($12.24). The high cost for fall fingerling plants was caused by very poor returns during drought years. During drought years, cost per fall fingerling creeled was $23.20, compared to only $1.32 in normal or high water years.

In addition to being the most cost-effective plant, spring fingerlings exhibited the best growth rates. The mean growth rate for spring fingerlings was 0.62 mm/d. Fall fingerling growth averaged 0.53 mm/d, followed by catchables at only 0.40 mm/d.

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INTRODUCTION

Rainbow trout *Oncorhynchus mykiss* are the most popular game fish in Idaho (Reid 1989). In 1987, an estimated 26% of all angling effort in Idaho was directed at trout in lowland lakes and reservoirs. Most of these fisheries are supported by put-grow-and-take hatchery plants of fingerling and catchable-sized (catchables) fish. About 75% of the catchables and 90% of the fingerling rainbow trout produced by the Idaho Department of Fish and Game (IDFG) are stocked in lowland lakes and reservoirs. Hatchery trout provide much of the consumptive harvest opportunity in these waters. Hatchery trout programs, however, are expensive. Production costs for hatchery rainbow trout make up about 35% of the annual resident fisheries budget.

The dependence of many lake and reservoir fisheries on hatchery trout and the cost of the hatchery program make it important to maximize stocking efficiency. This means determining the optimal time, size, and density of fish to be planted to maximize return-to-the-creel in each water. In the past, few stocking evaluations in Idaho compared the relative returns of fingerling and catchable-sized fish in lakes and reservoirs (Dillon and Megargle 1994). Stocking strategies are based on the experience and trial-and-error of individual fisheries managers. As with most other state agencies, IDFG has no standardized approach to determine appropriate stocking strategies. There are return targets for put-grow-and-take fisheries (100% by weight) and put-and-take fisheries (40% by number) (IDFG 1990), but it is unclear how often these objectives are met.

In 1992, IDFG began new statewide stocking evaluations to better define the tradeoffs between various put-and-grow trout stocking strategies in Idaho lakes and reservoirs. In this report we summarize data collected through 1997. This project is ongoing, and final results will be used to develop statewide trout stocking guidelines. This report documents progress toward that goal.

PROJECT GOAL

To maximize the effectiveness of trout stocking programs in Idaho.

OBJECTIVES

1. Describe growth, return, and cost per fish in the creel for fingerling and catchable-sized rainbow trout in selected put-grow-and-take waters statewide.

2. Describe relationships among lake and reservoir characteristics and performance of stocked rainbow trout.

3. Describe general characteristics of successful fingerling rainbow trout stocking programs.

4. Describe relationships among lake characteristics, angling effort, stocking rate, growth, and return of stocked fingerling and catchable-sized rainbow trout.

5. Develop stocking guidelines for put-grow-and-take rainbow trout fisheries in Idaho lakes and reservoirs.

6. Develop hatchery fish evaluation guidelines for lakes and reservoirs.

METHODS

Since 1992, we have evaluated stocking programs on 20 study waters (Figure 1). Each study water received plants of catchable and fingerling rainbow trout. The catchables were stocked in the spring and ranged in size from 200 mm to 250 mm total length. Fingerlings were planted in both spring and fall periods and ranged in size from 75 mm to 175 mm. Stocking densities for each group were not standardized and were based on manager requests. After release, we monitored the relative success of each plant using randomized creel surveys. Catchables were identified using various combinations of maxillary and fin clips. Fingerlings were marked only when needed to differentiate between spring and fall releases, or to identify different strains stocked at the same time. Unmarked fish were differentiated by size and fin erosion patterns.

We used harvest estimates from creel surveys, planting records, and production costs to estimate cost per fish creeled for each plant. We assumed production costs were $1.61 per pound (IDFG 1997). Total plant costs for each stocking event were estimated by multiplying the pounds of fish stocked by the production costs ($1.61 per pound). Cost per fish creeled was estimated by dividing the total plant cost by the number of fish harvested.

We assumed the majority of harvest from each plant would occur within three years of stocking. In many of the waters, however, we did not collect three years of consecutive creel data. If less than three years of creel data were collected, we applied correction factors to estimate total return of a plant. The correction factors were derived based on results from waters with three years of consecutive creel data. For catchables (n = seven waters), the mean percentages of harvest occurring in the first, second, and third years were 89%, 10%, and 1%, respectively. Similarly, the mean percentage of harvest for spring fingerlings (n = 4) was 32% in the first year, 53% in the second, and 15% in the third. For fall fingerlings (n = 8), the correction factors were 0%, 89.6% and 10.4%. Correction factors were used as follows: if we estimated harvest of a catchable plant to be 100 fish in the first year and 10 fish the second, but no creel was completed in the third year, total harvest would be 111 fish (110 fish/0.99 = 111).

In addition to estimating harvest and cost per fish creeled, growth of each release group was monitored by recording total length (mm) and weight (g) of creeled fish. In some waters, electrofishing and gillnet surveys were also used to increase sample sizes for growth analysis and help distinguish planting groups. Growth among plant groups was compared by estimating mean monthly increase in total length during the first 12 months of reservoir life.

RESULTS

Cost per fish creeled was estimated for 72 different plants (34 catchables, 22 fall fingerlings, and 16 spring fingerlings). On average, spring fingerlings were the most cost-efficient plant at $2.05 per fish creeled (Figure 2). Catchables returned at $2.61 per fish creeled, with one outlier of $402.30 removed. Fall fingerlings were the most costly plant at $12.24. The high value for fall fingerlings resulted from very poor returns during drought years. During drought years (1992 and 1994), cost per fall fingerling creeled was $23.20 compared to only $1.32 in normal or high water years (1993,1995,1996,1997) (Figure 3). Cost per fish creeled, percent return, and fishing pressure estimates are reported for each study water in Appendix A.

Cost per fish creeled was less variable for catchable and spring fingering plants than for fall fingerlings. Costs for catchables ranged from $0.44 to $402.30 per fish creeled. Despite one extreme value ($402.30), catchables had the lowest overall percentage (8.8%) of plants costing more than $5.00 per fish creeled (Figure 4). Because of high rearing costs, however, none of the 34 catchable plants returned at a cost less than $0.50 per fish. Conversely, 43.8% of the spring fingerling plants returned at a cost of less than $0.50 per fish. Costs for spring fingerlings ranged from $0.05 to $9.22 per fish creeled. Costs for fall fingerlings ranged from $0.35 to $83.56, with 31.8% of the evaluations exceeding a cost of $5.00 per fish creeled.

On average, growth of fingering plants was superior to catchables. Growth for catchables ranged from 0.63 mm/d in Chesterfield Reservoir to 0.17 mm/d in Little Wood Reservoir. For spring fingerlings, the best growth was observed in Roseworth Reservoir at 0.89 mm/d (1.1 in per month). Interestingly, fish growth in Little Wood Reservoir was at the bottom of the scale for all three plant types (Appendix B). Pooled results showed mean growth was greatest for spring fingerlings at 0.62 mm/d (0.7 in per month) (Figure 5). Mean growth was 0.53 mm/d for fall fingerlings and 0.40 mm/d for catchables (0.48 in per month).

DISCUSSION

The fingerling-catchable project is a long-term study that began in 1992. To date, 72 plants in 20 waters have been analyzed. Most of the data are summarized in Dillon and Alexander (1995 and 1996). Since the report of Dillon and Alexander (1996), we completed evaluations on Roseworth and Mormon reservoirs. In this report, we add recent findings to the database and focus mainly on describing the economic tradeoffs and growth potential of spring fingerling, fall fingerling, and catchable-sized plants in lakes and reservoirs.

To date, spring fingerlings have out-performed fall fingerling and catchable plants. The mean cost per spring fingerling creeled was $2.05. The average cost for catchable plants was $2.61. On average, fall fingerlings have demonstrated the poorest returns ($12.24 per fish creeled). Spring fingerlings also demonstrated the best growth. Mean growth during the first year after release was 0.62 mm/d for spring fingerlings, 0.53 for fall fingerlings and 0.40 for catchables.

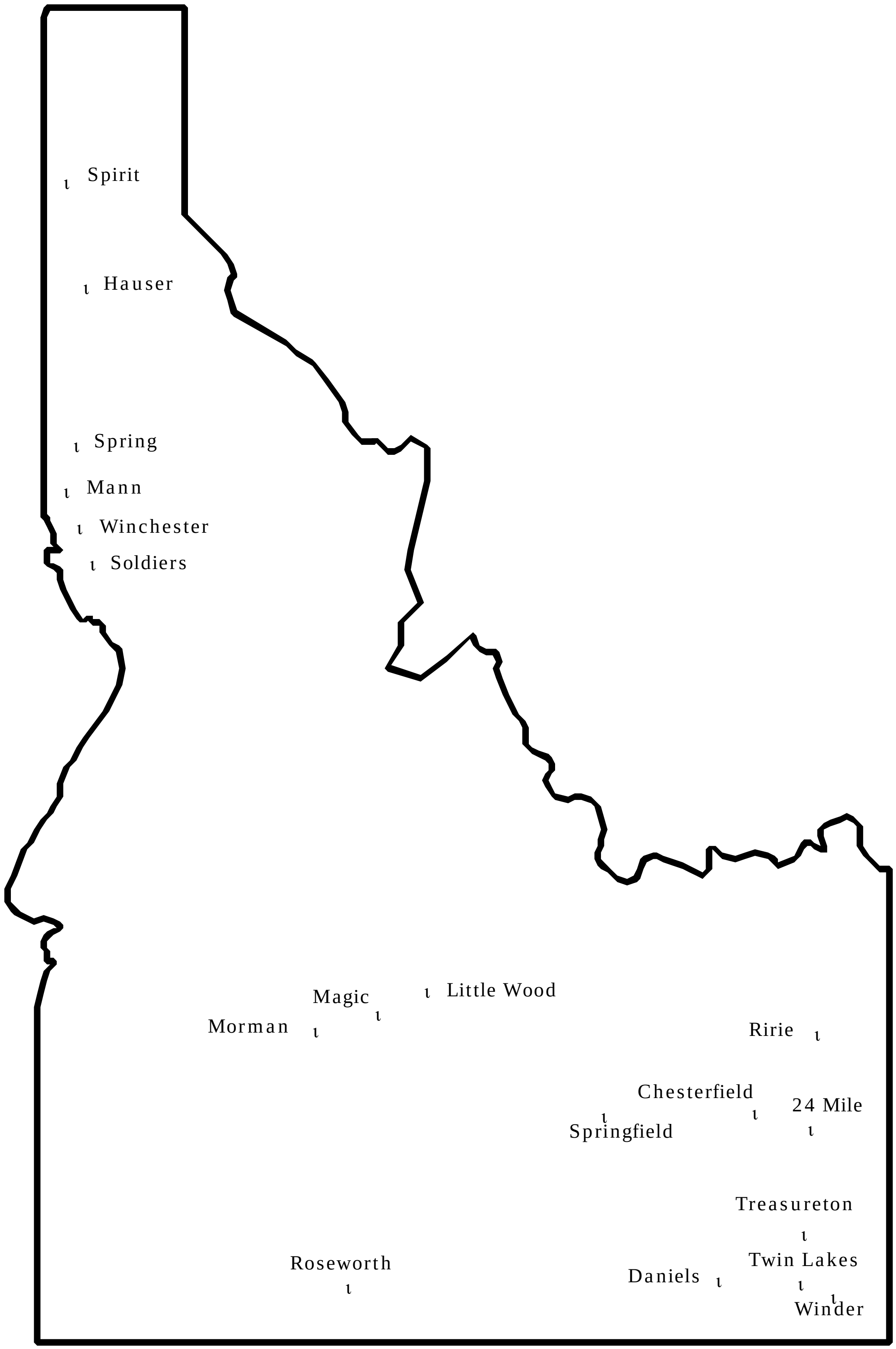

Figure 1. Location of waters included in the fingerling and catchable evaluations.

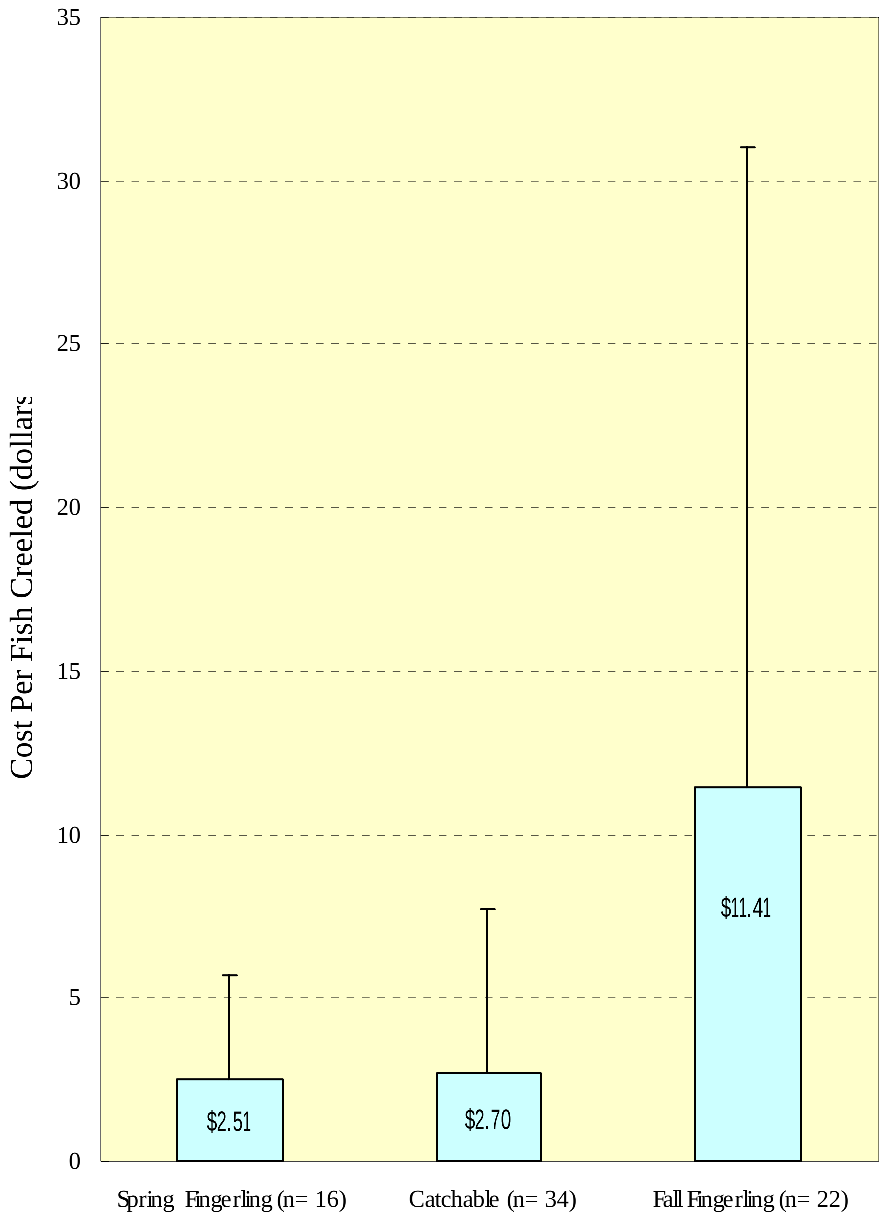

Figure 2. Mean cost per fish creeled for spring fingerlings, fall fingerlings, and catchable rainbow trout. Error bars equal one standard deviation.

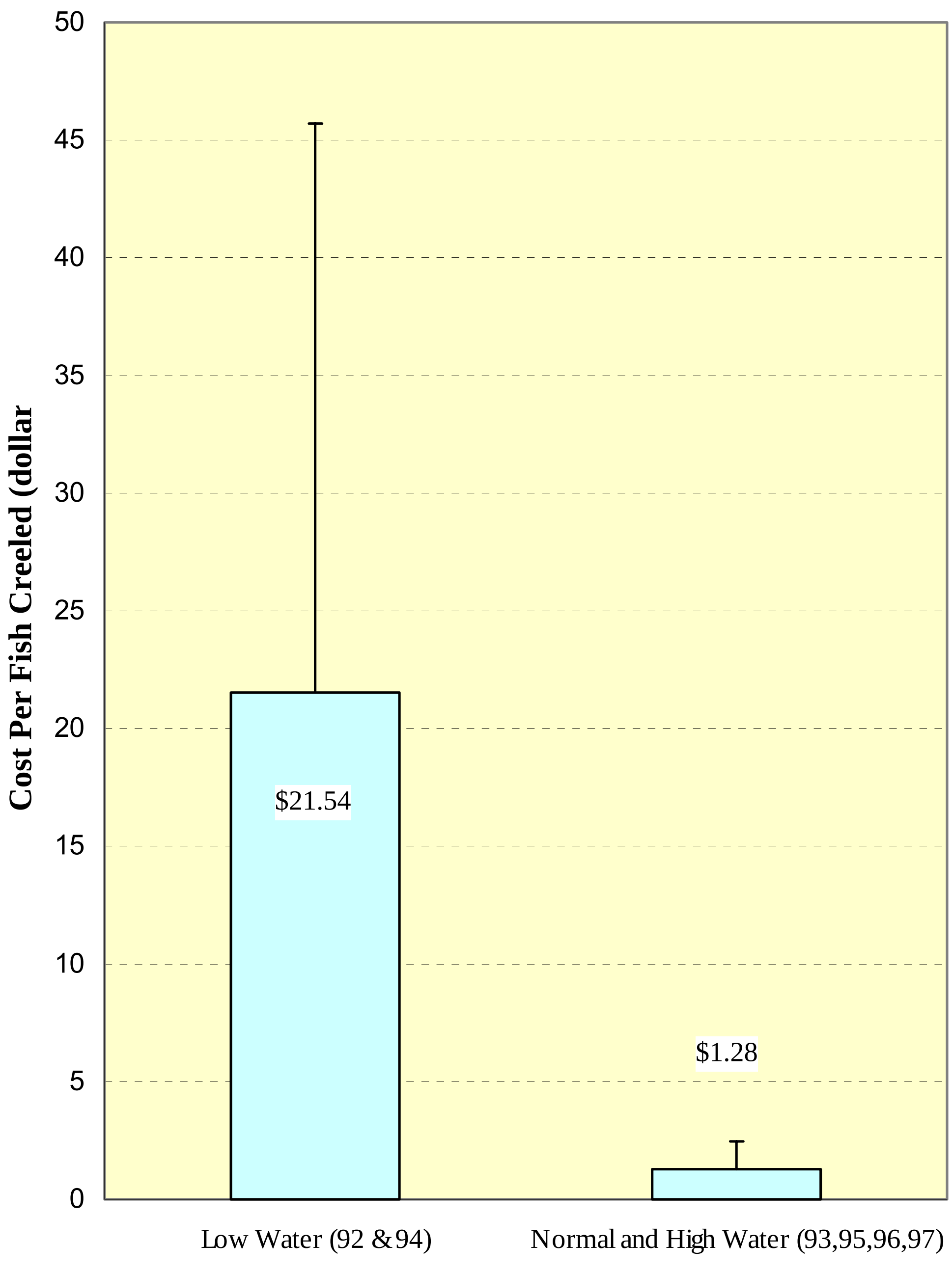

Figure 3. Mean cost per fish creeled for fall fingerling plants in drought (n = 11) and normal to high water years (n = 11). Error bars represent one standard deviation.

One of the objectives of this project was to identify the lake characteristics that predict stocking success. For fall fingerlings, water level and zooplankton abundance describe a significant proportion of the variation in stocking success. Dillon and Alexander (1996) reported fall fingerlings met management goals (100% return by weight) if large Cladocera (>2 mm) were present during the summer prior to stocking. Here, we found the costs of fall fingerlings increased from $1.32 per fish creeled in normal to high water years to $23.20 under drought conditions. Spring fingerlings and catchable plants appear to be less impacted by drought conditions. Water conditions failed to predict returns of spring fingerling or catchable plants. Future work should focus on identifying the lake characteristics that predict success of spring fingerling plants, especially because they appear to be the most cost-efficient release option.

The analysis presented in this report is preliminary and readers should consider the following limitation. First, identification of unmarked fingerlings was problematic and became increasingly difficult as the fish aged. It is likely that after two years of reservoir life, length frequency methods were unable to accurately differentiate spring from fall fingerling plants. Secondly, in waters where wild rainbow trout contribute to the creel (e.g., Magic Reservoir), we may have overestimated the return of fingerling plants. This would negatively bias cost per fish creeled estimates. Although harvest of wild fish is a known source of error, the impact on our results is considered minor because most of the study waters do not support natural recruitment. Finally, failure to incorporate fish that anglers released is probably the most significant limitation of this study. We did not include released fish because we had no way of knowing if released fish were stocked as fingerlings or catchables, when they were stocked, or how big they were. The absence of released fish biased our results by underestimating the true value of a stocking event. Furthermore, we anticipate the bias to be greater in trophy regulation waters. For example, in Mormon Reservoir in 1996, about 50% of the rainbow trout caught by anglers were released. If more of the released fish caught in Mormon Reservoir had been harvested, the cost per fish creeled value would have been lower. Conversely, in a general regulation water such as Little Wood Reservoir, only 14% of the rainbow trout caught in 1992 were released. Based on our analysis, Little Wood Reservoir would probably have a lower cost per fish creeled value than Mormon Reservoir, but the overall percent of fish caught from a stocking event may be equal or higher in Mormon Reservoir.

Many of the fingerling-catchable project objectives were not addressed in this report (i.e., suggesting stocking densities and describing the lake characteristics which define successful spring fingerling and catchable plants). Additional data are needed to address all the objectives of the fingerling-catchable tradeoffs project. When sufficient data have been collected, a final report will be completed.

RECOMMENDATIONS

1. In reservoirs, consider early release of fall fingerling trout when spring snow pack levels are low and a significant summer draw down is expected.

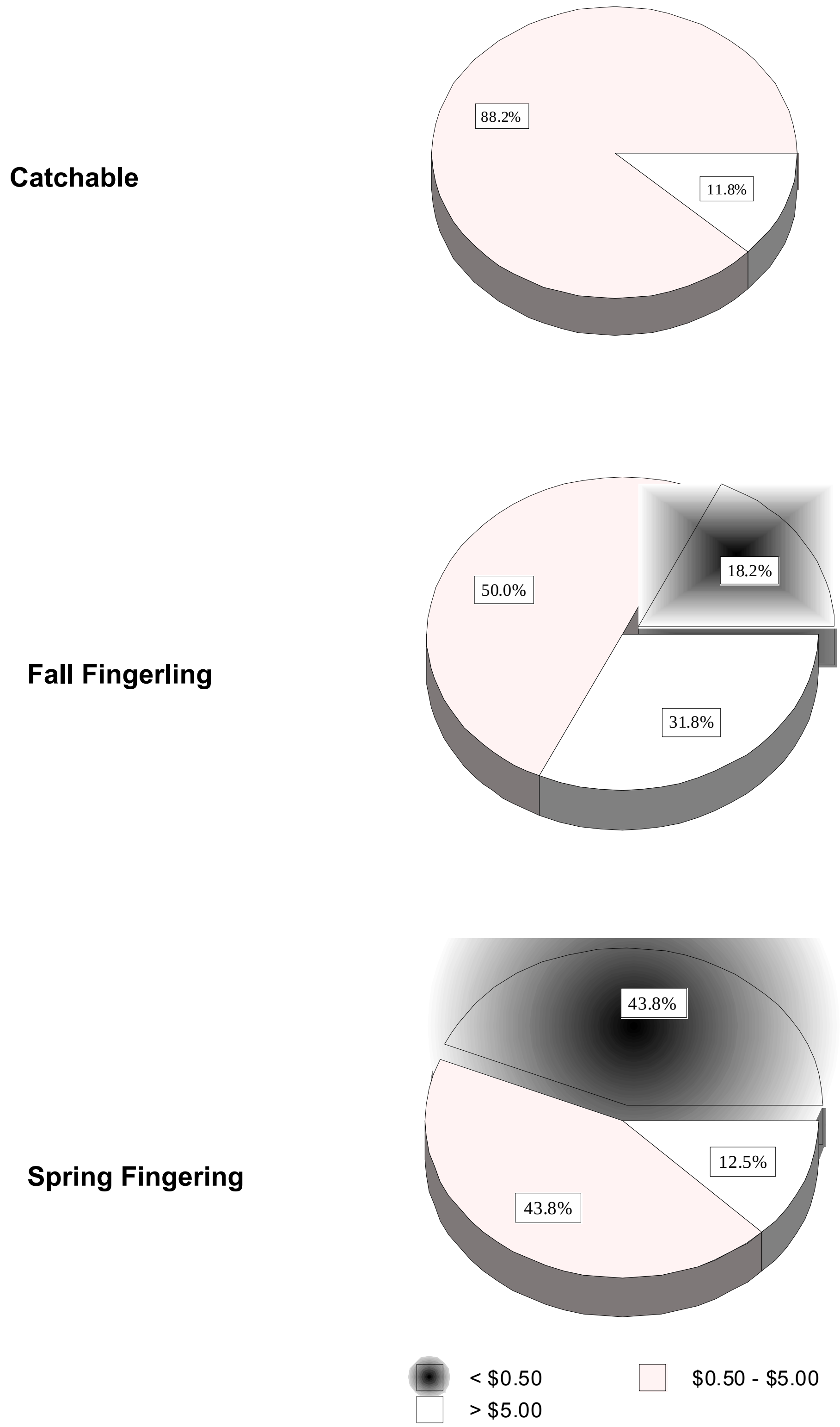

Figure 4. Percent of Idaho lake and reservoir stocking events costing less than $0.50, between $0.50 and $5.00, and more than $5.00 per fish creeled.

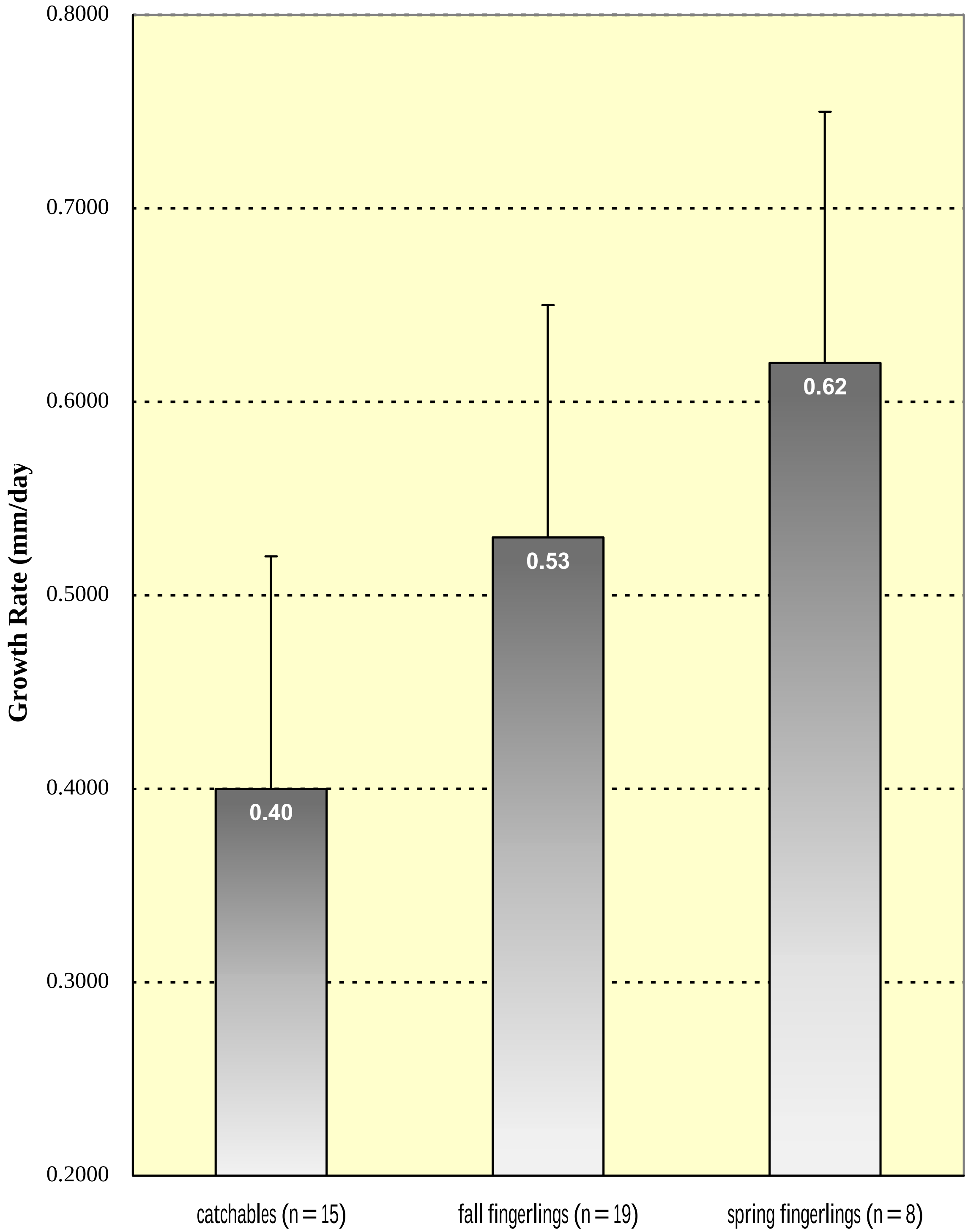

Figure 5. Growth rate (mm/d) for spring fingerlings, fall fingerlings, and catchables. Sample size for each plant group is indicated. Growth rates for each plant group were estimated for the first year of reservoir life. Error bars represent one standard deviation.

ACKNOWLEDGEMENTS

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APPENDICES

Appendix A. Estimated cost per fish creeled, fishing effort, fishing pressure, and percent returns for spring fingerling, fall fingerling, and catchable rainbow trout in 16 Idaho lakes and reservoirs.

Lake	Surface area (ha)	Survey year	Plant year	Fish Type [a]	Fish Length (mm)	Number stocked	Stocking density (#/ ha)	Weight stocked (kg)	Total plant costs ($)	Fishing effort (hrs)	Fishing pressure (hrs/ha)	% Return	Cost per fish creeled
Spirit Lake	1,700	92	92	c	9.50	7,000	4	1,054	3,924	31,337	54	7.2	7.44
Hauser Lake	245	93	92	ff	5.34	20,000	82	527	1,948			6.5	1.45
		93	93	c	9.98	9,000	37	1,571	5,861	35,392	240	87.1	0.71
Spring Valley	21	93	92	ff	6.40	10,000	476	401	1,688			0.7	21.28
		93	93	c	9.95	45,000	2,143	9,737	29,037	35,226	1610	60.4	1.27
		93	93	sf	3.95	20,000	952	165	779			9.2	0.32
Mann Lake	49	93	93	c	9.95	42,490	867	9,340	27,417	30,994	766	64.2	1.22
		93	93	sf	3.87	45,000	918	372	1,648			1.3	2.30
Winchester Lake	34	93	92	ff	5.96	10,000	294	378	1,360			4.0	3.34
		93	93	c	9.95	42,288	1,244	8,285	27,287	43,030	1418	67.9	1.02
Soldier Meadow	41	93	93	c	9.65	15,070	368	2,490	8,860	14,973	366	88.6	0.66
		93	93	sf	4.01	25,000	610	206	1,020			29.6	0.10
Magic	729	92-95	92	c	8.82	33,850	46	3,773	15,144	60,716	300	28.4	1.39
		92-95	92	sf	3.27	201,400	276	1,682	4,421			3.9	0.76
		92-95	92	ff	4.72	97,345	134	1,955	6,517			0.1	71.30
		93-95	93	c	8.70	36,400	50	4,000	15,621	52,242	57	33.4	1.17
		93-95	93	sf	3.94	387,050	531	3,284	14,968			1.1	2.74
		93-95	93	ff	5.43	50,868	70	1,841	5,213			5.5	2.34
		93-95	93	ff	5.16	216,345	297	5,523	18,988			5.8	1.56
		94-95	94	c	7.91	24,975	34	2,523	8,026	71,656	358	13.3	2.70
		94-95	94	ff	4.84	50,170	69	1,318	3,625			0.1	83.56
		95	95	sf	5.15	315,338	433	2,545	27,513			1.0	3.00
		95	95	c	10.00	33,900	47	5,909	22,210	47,617	39	28.5	2.17
Little Wood	238	92-95	92	c	9.02	7,600	32	1,119	3,640	14,929	250	38.2	1.37
		92-95	92	sf	3.15	54,000	227	371	1,058			8.8	0.28
		92-95	92	ff	4.92	15,000	63	286	1,139			0.3	22.52
		93-95	93	c	9.84	10,113	42	1,761	6,309	18,074	89	87.9	0.70
		93-95	93	sf	3.07	48,600	204	214	881			29.7	0.05
		93-95	93	ff	4.92	54,000	227	1,140	4,101			21.7	0.35
		94-95	94	c	9.96	10,000	42	1,761	6,472	26,601	443	74.9	0.84
		94-95	94	sf	3.30	59,901	252	390	1,352			20.7	0.11

Appendix A. Continued.

Lake	Surface area (ha)	Survey year	Plant year	Fish Type [a]	Fish Length (mm)	Number stocked	Stocking density (#/ ha)	Weight stocked (kg)	Total plant costs ($)	Fishing effort (hrs)	Fishing pressure (hrs/ha)	% Return	Cost per fish creeled
Little Wood, continued.													
		94-95	94	ff	5.00	10,000	42	226	798			1.6	5.14
		95	95	c	10.31	5,000	21	1,000	3,594	54,653	230	18.1	3.93
Springfield	26	92-94	92	c	9.98	6,754	260	1,209	4,398	3,444	129	12.8	4.96
		92-94	92	ff	6.21	25,008	962	1,088	3,853			15.2	1.02
		93-94	93	c	8.58	8,500	327	976	3,497	16,900	633	0.1	402.30
		93-94	93	ff	6.12	28,885	1,111	1,202	4,257			5.2	2.82
Twin Lakes	181	92-94	92	c	9.60	11,076	61	1,769	6,410	13,639	84	37.0	1.53
		92-94	92	ff	6.40	37,630	208	1,782	6,354			11.6	1.45
		93-94	93	c	8.51	11,141	62	1,247	4,471	39,312	218	21.2	1.88
		93-94	93	ff	5.88	37,637	208	1,388	4,912			28.8	0.45
		94	94	c	8.93	11,150	62	1,247	5,180	38,289	211	29.5	1.35
Winder	38	92-94	92	c	9.47	13,198	347	2,052	7,328	13,295	547	60.6	0.91
		92-94	92	ff	6.25	9,944	262	460	1,562			0.6	27.37
		93-94	93	c	8.52	2,349	62	263	946	11,056	291	29.3	1.36
		93-94	93	ff	5.50	6,450	170	195	687			19.0	0.57
		94	94	c	8.94	2,350	62	263	1,095	17,317	577	39.3	1.01
Treasureton	63	92	92	c	9.41	15,960	253	2,381	8,692	11,085	350	41.0	1.29
		93	93	c	9.02	16,002	254	1,746	7,664	23,896	412	88.7	0.44
Chesterfield	645	92-94	92	c	7.60	20,000	31	1,588	5,692	5,903	35	7.2	3.91
		92-94	92	ff	6.30	134,995	209	6,226	21,728			1.0	16.37
		93-94	93	c	9.02	39,995	62	4,491	19,154	28,589	44	34.7	1.15
		93-94	93	ff	6.50	129,850	201	5,557	22,982			37.9	0.40
		94	94	c	9.06	40,000	62	4,480	19,416	150,151	359	46.5	0.86
Ririe	632	93	92	sf	4.94	162,530	257	4,159	12,496			6.0	1.52
		93	93	c	12.10	12,019	19	3,848	14,052	56,612	90	61.1	1.86
Mormon	1,092	96-97	95	c	8.70	8,880	8	1,029	3,811			62.4	0.66
		96-97	95	sf	5.40	47,940	44	1,337	4,831			1.6	6.17
		96-97	95	ff	4.50	70,740	65	1,145	4,096			15.1	0.38
		96-97	96	c	9.40	4,830	4	705	2,622	24,740	23	20.7	2.51
		96-97	96	sf	4.70	60,480	55	1,114	3,997			0.7	9.22
		96-97	96	ff	5.40	61,060	56	1,703	6,153			8.4	1.18
		97	97	c	8.90	5,060	5	627	2,327	39,663	36	1.6	28.01
		97	97	sf	4.73	150,950	138	2,835	10,171			1.6	4.19

Appendix A. Continued.

Lake	Surface area (ha)	Survey year	Plant year	Fish		Number stocked	Stocking density (#/ ha)	Weight stocked (kg)	Total plant costs ($)	Fishing effort (hrs)	Fishing pressure (hrs/ha)	% Return	Cost per fish creeled
				Type [a]	Length (mm)								
Roseworth	607	96-97	95	c	9.10	15,000	25	1,987	7,379			22.9	2.05
		96-97	95	sf	3.60	33,800	56	281	994			2.5	1.19
		96-97	95	ff	6.10	30,100	50	1,208	4,392			24.2	0.59
		96-97	96	c	8.90	15,000	25	1,860	6,897	27,318	45	34.4	1.28
		96-97	96	sf	3.00	65,000	107	313	1,098			4.1	0.41
		96-97	96	ff	5.40	20,300	33	566	2,046			2.6	3.86
		97	97	c	9.30	15,000	25	2,120	7,883	21,725	36	20.0	2.51
		97	97	sf	2.90	50,290	83	219	766			3.2	0.49

[a] Abbreviations: c = catchable, ff = fall fingerling, sf = spring fingerling.

Appendix B. Growth rates (mm/d) for catchables and spring and fall fingerlings.

System	Year	Initial day	Final day	Initial length	Final length	Growth (mm/d)
			Catchables			
Little Wood	94	05/13/94	05/11/95	252	313	0.17
Little Wood	93	05/04/93	05/24/94	250	326	0.20
Winder	93	05/08/93	06/01/94	257	353	0.25
Roseworth	96	03/15/96	05/27/97	230	375	0.33
Daniels	92	03/31/92	05/06/93	196	333	0.34
Magic	93	05/26/93	06/12/94	246	393	0.38
Mtn. Home	95	03/14/95	05/22/96	231	418	0.43
Magic	92	05/07/92	06/17/93	223	401	0.44
24 Mile	93	05/12/93	06/09/94	229	410	0.46
Mormon	95	05/15/95	05/20/96	230	405	0.47
Treasureton	93	05/06/93	06/08/94	229	418	0.47
Roseworth	95	03/22/95	05/21/96	231	434	0.48
Mormon	96	05/10/96	05/12/97	242	421	0.49
Daniels	93	05/07/93	06/07/94	229	427	0.50
Chesterfield	93	05/03/93	06/07/94	229	480	0.63
			Spring Fingerlings			
Little Wood	92	04/13/92	05/01/93	80	270	0.50
Mormon	96	05/10/96	05/28/97	119	310	0.50
Little Wood	93	05/08/93	05/24/94	78	287	0.55
Magic	93	04/09/93	04/17/94	100	315	0.58
Mormon	95	05/05/95	05/20/96	137	365	0.60
Roseworth	96	04/15/96	05/27/97	76	330	0.62
Magic	92	04/02/92	06/17/93	83	404	0.73
Roseworth	95	04/27/95	05/21/96	93	442	0.89
			Fall Fingerlings			
Little Wood	92	09/16/92	10/13/93	125	260	0.34
Little Wood	93	09/27/93	10/12/94	125	259	0.35
Treasureton	93	09/21/93	09/07/94	152	287	0.38
Winder	93	09/21/93	10/25/94	127	283	0.39
Magic	94	09/21/94	09/13/95	123	291	0.47
Twin L.	93	09/21/93	09/20/94	152	328	0.48
Magic	93	10/13/93	10/11/94	138	314	0.48
Magic	93	10/08/93	10/11/94	131	310	0.49
Twin L.	92	09/28/92	09/21/93	163	340	0.49
Roseworth	96	09/09/96	09/04/97	137	335	0.55
Roseworth	95	09/06/95	09/09/96	157	367	0.57
Chesterfield	93	09/20/93	09/07/94	165	370	0.58
24 Mile	93	09/22/93	09/08/94	152	357	0.58
Mormon	96	09/11/96	09/08/97	137	349	0.59
24 Mile	92	09/28/92	09/22/93	160	380	0.61
Daniels	93	10/25/93	10/05/94	127	340	0.62
Daniels	92	09/28/92	09/20/93	162	384	0.62
Mormon	95	09/01/95	09/13/96	114	373	0.69
Springfield	92	10/01/92	10/22/93	157	482	0.84

JOB PERFORMANCE REPORT
SUBPROJECT #2: STERILE TROUT INVESTIGATIONS

State of: Idaho   Grant No.: F-73-R-20, Fishery Research

Project No.: 8   Title: Hatchery Trout Evaluations

Subproject.: 2, Sterile Trout Investigations

Contract Period: July 1, 1997 to June 30, 1998

ABSTRACT

Triploid rainbow trout *Oncorhynchus mykiss* may have important applications in fishery management programs. Triploids are functionally sterile and do not pose genetic risks to indigenous populations. Sterile fish may also grow faster and live longer than normal diploid fish. We began research in 1996 to develop methods to produce triploid rainbow trout and triploid rainbow trout X cutthroat trout *O. clarki* hybrids. We also began testing the performance of sterile trout in recreational fisheries. In 1997, we achieved 100% triploid induction rates in several heat shock treatments for Hayspur strain (R-9) rainbow trout. The 100% triploid groups were produced by submersing fertilized eggs in a 26°C water bath for 20 min. In addition to an excellent induction rate, mean survival to hatch in the 26°C treatments averaged 100% of survival observed in control groups.

In 1997, 18 streams were stocked with sterile catchables and we began monitoring growth and survival of sterile fingerling rainbow trout stocked in seven reservoirs. Results from the stream study indicated return-to-the-creel was similar between sterile and control catchables. Total tag returns were 17.2% for sterile fish and 17.0% for controls. Culture performance, however, was modestly lower in the sterile group. Survival to plant was 60% for the sterile fish and 88% in the controls. Estimated rearing costs per catchable were $0.38 for sterile fish and $0.33 for controls. Preliminary results from reservoir evaluations showed growth and survival of age-1 sterile and control fish varied among reservoirs but was similar when comparing results within a water. Combined catch from electrofishing and gillnet surveys was 65 sterile fish and 53 controls. Length at age-1 varied less than 5% between stocking groups.

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INTRODUCTION

Over the last decade, the production and use of sterile fish as a fishery tool has received increasing attention. Rationale for using sterile fish in stocking programs is generally based on two distinct and separate needs: 1) the desire for a longer-lived, faster growing hatchery product; and 2) protecting the genetic integrity of indigenous stocks. Although early researchers focused on the predicted growth and longevity benefits and the trophy potential of sterile fish, such benefits have not been documented in recreational fisheries.

With or without growth benefits, sterile fish represent a fishery management tool with potentially broad applications. For example, the demand for consumptive trout fishing in Idaho is largely met by stocking hatchery rainbow trout *Oncorhynchus mykiss* catchables in selected streams. Despite recent emphasis on wild trout management, about 40% of stream plants occur in waters with viable trout populations (IDFG, unpublished data). Using sterile rainbow trout catchables to meet these demands would minimize concerns for genetic impacts on indigenous rainbow trout and cutthroat trout *O. clarki*.

Sterile fish may also be useful in mountain lake stocking programs as both a genetic conservation and a fishery enhancement tool. Hatchery-reared trout and Arctic char *S. alpinus*, which mature in mountain lakes, may emigrate at high rates if an outlet is accessible (Warrillow et al. 1997). This represents a loss to the lake fishery as well as a potential for genetic impacts on downstream indigenous stocks. Additionally, in some mountain lakes with spawning habitat, fertile hatchery fish may overpopulate and stunt. If sterile fish are less likely to emigrate and will not reproduce, then improvements in the numbers and size structure could result.

Techniques to produce sterile salmonids are well developed, particularly within the aquaculture industry, and triploid rainbow trout eggs are available from many commercial egg suppliers. The most widely used approach is chromosome manipulation, specifically for induction of triploidy. Triploidy is induced by thermal, pressure, or chemical shock of eggs shortly after fertilization. This causes retention of the second polar body of the egg and results in an embryo with two sets of maternal and one set of paternal chromosomes. Triploid salmonids are functionally sterile, although males may still develop secondary sex characteristics and exhibit spawning behavior (Feist et al. 1996).

Another less-refined technique for producing triploid salmonids is by spawning tetraploid fish with normal diploid fish. Tetraploids are produced by shocking fertilized eggs just before the first cell division. Tetraploid salmonids appear to be less viable, but are fertile. Resultant sperm and eggs contain two compliments of chromosomes rather than the normal one. Spawning with normal diploid fish will theoretically produce all-triploid offspring (Eric Wagner, Utah Department of Natural Resources, personal communication).

Although production techniques are fairly well developed, information on performance of triploid salmonids in recreational fisheries is lacking (Simon et al. 1993). Sterile fish must survive, grow, and return to anglers at rates comparable to normal fish if they are to be useful in stocking programs.

MANAGEMENT GOAL

To minimize genetic risks to indigenous rainbow trout and cutthroat trout from hatchery trout and enhance hatchery-supported lake and reservoir fisheries.

OBJECTIVES

1. Evaluate return-to-the-creel of commercially-supplied triploid rainbow trout and normal rainbow trout in put-and-take stream fisheries.

2. Evaluate relative survival and growth of triploid and normal rainbow trout fingerlings in lakes and reservoirs.

3. Refine techniques to produce and evaluate the performance of triploid Henry's Lake cutthroat trout X rainbow trout hybrids.

4. Develop techniques to produce triploid fish using Hayspur strain rainbow trout for future stream and reservoir stocking programs.

METHODS

Sterile Stream Catchables

In 1996, we purchased 20,000 sterile triploid and 20,000 control diploid rainbow trout eggs from Mt. Lassen Trout Farms, Inc. in Red Bluff, California. Triploidy was induced by heat shocking eggs shortly after fertilization (Dan Brown, Mt. Lassen Trout Farms, Inc., personal communication). Eyed eggs were shipped on June 20 to IDFG's Nampa Fish Hatchery in Nampa, Idaho, where incubation and rearing took place. We assessed hatching rate and survival to feeding rates for both groups. We compared relative rearing costs per catchable-sized sterile and control fish using total egg costs plus total feed costs for each group.

When test fish reached adequate size for blood sampling, we sacrificed a total of 70 sterile and 10 control fish for confirmation of ploidy level. We collected blood from individual fish by severing the caudal peduncle, and fixed the blood in Alsever's solution. Samples were shipped on ice to the Washington State University Veterinary Sciences Lab, where each sample was evaluated for ploidy level using flow cytometry (Thorgaard et al. 1982; Utter et al. 1983).

From May 20 to July 27, 1997, we stocked each of 18 streams with 300 sterile and 300 control rainbow trout. Study streams were located throughout Idaho (Figure 1) and represented a broad range of stream sizes and productivities. All fish were anesthetized with carbon dioxide, tagged with size 8 Monel jaw tags, and held in hatchery raceways 8 h to 2 d prior to transport and stocking. Jaw tags were sequentially numbered to identify individual streams and treatment groups, and were stamped, "RTN IFG." A subsample of each stocked group was measured to the nearest mm (total length).

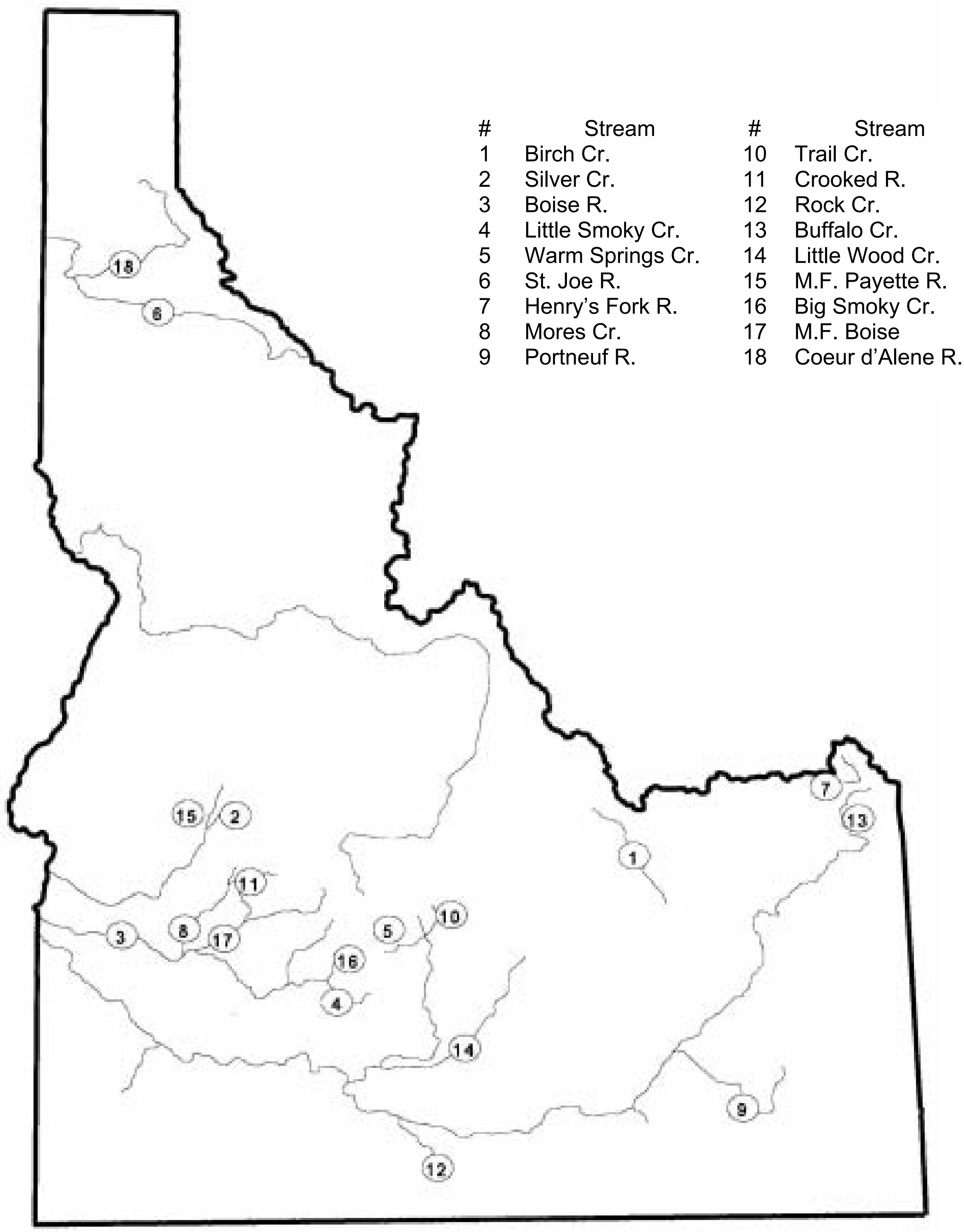

Figure 5. Location of waters included in the sterile stream evaluation.

To promote tag returns, we placed signs along stocked sections of each stream informing anglers of the presence of tagged fish and providing mail-in instructions. We specifically requested information on date and location of catch and angler address and phone number. As an incentive, we offered one chance at three gift certificates worth up to $200 for each tag returned. Because we sought only to compare relative returns for sterile and control fish, we did not attempt to adjust tag return data for non-response bias.

Data Analysis — We completed an a priori power analysis for paired-t tests as part of the experimental design process (Cohen 1988; Peterman 1990). To choose an effect size we subjectively assumed if sterile fish return to the creel at 75% the rate of normal fish (effect size 0.25), most fishery managers would elect to use them to reduce genetic risks to native stocks. We further assumed a range of tag return rates among streams (10% to 70%) and that return of sterile and control fish within streams would be highly correlated (r = 0.80). We set α= 0.10. Based on these assumptions, our design with 18 paired stocking events would provide a 98% chance of avoiding type II error for the above effect size.

We used a two sample t-test (Zar 1974) to compare mean total length at stocking (mm) for sterile and control fish in each stocking event. We compiled tag return data (through October 31, 1997) for sterile and control fish by stream and by time (d) between stocking and harvest. We used a paired-t test (Zar 1974) to test the hypothesis that the mean difference in tag returns from sterile and control fish was not significantly different from zero. In addition, we derived an estimate of mean time to harvest (d) for each stocked group and stream using stocking dates and the harvest dates provided by anglers. A paired-t test was also used to test for a significant difference in mean time to harvest (d) for sterile and control fish.

Sterile Fingerlings in Lakes and Reservoirs

In April 1996, IDFG received 60,000 all-female triploid (sterile) rainbow trout eggs from Trout Lodge and an equal number of all-female diploids (control). These eggs were scheduled for use as fall 1996 fingerling plants in lakes and reservoirs statewide. They were hatched and reared at Nampa Fish Hatchery. Prior to release, we differentially marked the sterile and control groups with fluorescent grit dye (Nielson 1990). Sterile fish were dyed red and controls green. In October 1996, the fingerlings were stocked in roughly equal proportions in seven waters (Table 1). To assess relative survival and growth, a combination of gillnetting and electrofishing surveys were completed.

Data Analysis — A chi-square test will be used to compare relative survival through age-3. An attempt will be made to collect a minimum of 172 grit-marked fish from each study water. Data from different sampling gear and time periods will be pooled if the data pass a standard chi-square test of homogeneity (Elrod and Frank 1990). If we sample 172 fish, we will be able to detect a 20% change from a stocking ratio of 50:50 (α = 0.10; 1 - B = 0.80). A two-factor analysis of variance will be used to test the hypothesis that there is no significant difference in mean fork length between the sterile and control rainbow trout at age-1, age-2, and age-3 (α = 0.10). Lakes will be considered a random effect and ploidy considered fixed.

Triploid Induction

Prior to beginning induction trials, we completed a literature review of methods used for inducing sterility in hatchery reared rainbow trout (Appendix A). Results of the literature review indicated chemical, temperature, and pressure shocks have all been effective at producing triploid rainbow trout. The most commonly reported, however, was temperature shock (see Appendix A). Given those results, we completed a series of induction trials at three temperatures (26°C, 27°C, and 28°C) applied from 10 min to 25 min after fertilization (MAF). Hayspur strain rainbow trout (R-9) and rainbow trout X cutthroat trout hybrids were used for induction experiments. Specific methods for each experiment are described below.

Table 1. Total catch of sterile and control rainbow trout stocked as fingerlings in fall of 1996. All rainbow trout were age-1. Effort was recorded as net nights (Nets) and electrofishing hours (Elec.).

System	Acres	Regulations	Stocked		Total Catch		Effort		Mean Length (mm)	
			Sterile	Fertile	Sterile	Fertile	Nets	Elec.	Sterile	Fertile
Daniels R.	375	Trophy [a]	7,965	7,938	21	16	1.5	4.9	187	183
Treasureton R.	143	2 (12-16 slot)	5,900	6,030	19	23	1.0	0.0	266	267
Brundage R.	340	2 (12 -20 slot)	1,003	1,016	7	1	6.0	0.0	183	164
L. Payette R.	1,450	Trophy	5,015	5,080	1	0	12.0	0.0	195	-
Lost Valley R.	750	General	12,980	12,700	12	8	2.0	1.0	175	185
Warm L.	640	General	5,015	5,080	5	5	4.0	0.0	178	178
Tule L.	7	Trophy	100	100	0	0	1.0	0.0	-	-
Totals			**37,978**	**37,944**	**65**	**53**	**27.5**	**5.9**		

[a] Trophy waters have a 20-inch minimum size and a no bait restriction.

Hayspur Replicate #1

Four induction trials were completed (26°C at 15 MAF, 26°C at 20 MAF, 28°C at 15 MAF, and 28°C at 20 MAF) using age-2 broodstock on November 20, 1997. Spawn from five females and five males was combined in a 2.5 gal bucket and transported from the pond to the incubation building. Eggs were placed in heated water baths at 15 MAF and 20 MAF. The eggs were treated in plastic tubs (38 cm X 20 cm X 13 cm). Heat pumps were used to maintain water temperatures to within 0.3°C of desired levels. After 20 min, the eggs were removed from the tubs and placed in heath trays for incubation. After 17 d, live and dead egg totals were estimated using volumetric displacement techniques. Control eggs were not taken during this replicate. Therefore, survival to the eyed-egg stage was compared to production eggs taken the same day. Fry were reared at Hayspur Fish Hatchery until blood samples were analyzed for ploidy. Methods for completing blood analysis are described in the section on stocking sterile catchables in streams.

Hayspur Replicate #2

On December 16, 1997, we completed a second series of heat shock treatments (26°C at 10 MAF, 15 MAF, and 20 MAF; 28°C at 10 MAF, 15 MAF, and 20 MAF). Several adjustments were made to improve methods used in the first induction trials. The differences included: spawn from 20 fish (10 males, 10 females) was taken at the same time, age-3 fish were used, the start time for MAF began after adding fresh water to the spawn, the number of eggs taken per treatment was standardized by pouring 120 ml (2,000 eggs) of eggs into plastic treatment baskets (23 cm X 33 cm X 5 cm), the plastic treatment baskets were placed into the larger plastic tubs, and a control group of eggs was poured for each MAF treatment. Control eggs were placed in the same type of plastic treatment baskets and tubs as the treatment eggs. The control tubs were filled with ambient water from the hatchery building (11.2°C). Instead of using volumetric displacement, all eggs were hand-counted at the eyed stage. At the eyed stage, 400 eggs from each treatment were transported to the Eagle Fish Health Laboratory for rearing. The remaining eggs were incubated at Hayspur Fish Hatchery. Dead eggs were counted and removed from each treatment at weekly intervals and survival to hatch was estimated for each control and treatment group.

Hayspur Replicate #3

On January 30, 1998, we completed a third replicate using the methods described for Replicate #2. Due to hatchery space constraints, not all of the fry were reared to the blood analysis stage. This replicate was completed to increase our knowledge of egg mortality associated with heat shock treatments, include another replicate using older fish (age-4 to age-7+), and complete an induction experiment using 27°C treatments.

Henrys Lake Hybrids #1 and #2

Handling and induction methods were similar as those described for Hayspur broodstock. Sperm from Kamloops strain rainbow trout was used to fertilize cutthroat trout eggs collected at the Henry's Lake spawning trap. Induction trials were completed on March 5 and March 20, 1998 and followed the Hayspur Replicate #2 protocols. Eyed-eggs were shipped to the Eagle Fish Health Laboratory for rearing.

RESULTS

<u>Sterile Stream Catchables</u>

Hatch rates were lower for sterile fish (59.7%) than for control fish (87.7%). Most of the increased mortality of sterile fish occurred in the first two months. Survival between groups was similar thereafter. Estimated rearing costs per catchable were $0.38 for sterile fish and $0.33 for controls.

Results of the flow cytometry analysis (Paul Wheeler, Washington State University, unpublished data) indicated an unusually high rate of triploidy in the sterile group. All (n = 70) of the blood samples from putative sterile triploid fish were confirmed triploid by flow cytometry. The 10 control fish were all confirmed diploid.

There was a small but detectable difference in size at stocking for the two test groups. Mean total length at stocking was 272 mm (S.D. = 22 mm) for sterile fish and 256 mm (S.D. =

20 mm) in the controls. With a total of over 2,000 fish measured, this overall difference in size at stocking was significant (p <0.01).

Relative tag returns for sterile and control fish varied by location, but was similar overall. A total of 1,849 tags were returned from the 10,800 tagged fish stocked, for an overall return rate of 17.1% (Table 2). Because tag returns were not adjusted for non-response bias, true return-to-the-creel rates are unknown. Of the total tag returns for all 18 streams, 931 were from sterile fish and 918 from control fish. Results of the paired-t test indicated the overall difference in tag return rates were not significantly different from zero (p = 0.80).

For both stocked groups, most of the fish that returned to the creel were harvested relatively quickly. For all streams combined, the time (d) for returns to reach 50%, 75%, and 90% of the cumulative total was 24 d, 40 d, and 57 d, respectively. Timing of returns for sterile and control fish was quite similar overall (Figure 2), and there was no significant difference in mean time to harvest for the two groups (p = 0.35).

Sterile Fingerlings in Lakes and Reservoirs

Results from the 1997 sampling effort are shown in Table 1. Total catches of control and sterile fish were small but similar. Catch for all reservoirs combined was 65 sterile fish and 53 controls. Also, mean lengths of fish recorded during electrofishing and gillnet surveys indicated growth rates varied among reservoirs but were comparable between groups within a water (Table 1). Due to the limited number of fish sampled, no statistical comparisons were completed, but will conducted for age-2 fish next year.

Triploid Induction

Triploid induction rates for the Hayspur strain rainbow trout ranged from 91% to 100%. The highest induction rates were observed in the 26°C treatments (Table 3). Four of the five 26°C treatments were 100% triploid. Survival to hatch was also best in the 26°C treatments and ranged from 87% to 119% of controls. Also, survival to hatch was higher for age-4 spawners compared to age-2 fish. Mean survival to hatch for all treatments combined increased from 26% for age-2 spawners to 56% for age-4 and older fish. The increase in survival was observed in both treatment and control groups. Therefore, the survival differences were not attributed to the heat shock treatments. Results from Henry's Lake induction experiments were not available at the time this report was prepared.

Table 2. Stream width, total dissolved solids (TDS), plant date, and tag returns (uncorrected for non-response) from 18 Idaho streams stocked with 300 fertile and 300 sterile catchable rainbow trout. Stream width was a mean of at least four measurements taken at the fish planting location.

				Tag Returns			
Stream	**Plant Date**	**Width (m)**	**TDS (ppm)**	**Fertile**	**Sterile**	**Total**	**% Return**
Birch Cr.	May 5	8	238	137	118	255	42.5
Silver Cr.	June 25	11	26	78	82	160	26.7
Boise R.	July 9	16	42	73	73	146	24.3
Little Smoky Cr.	July 1	7	116	70	62	132	22.0
Warm Spring Cr.	July 1	9	101	63	63	126	21.0
St. Joe R.	July 16	28	37	45	76	121	20.2
Henry's Fork R.	May 20	45	67	56	54	110	18.3
Mores Cr.	July 10	11	66	39	64	103	17.2
Portneuf R.	July 15	17	310	51	46	97	16.2
Trail Cr.	July 27	11	227	43	46	89	14.8
Crooked R.	June 25	8	35	44	43	87	14.5
Rock Cr.	July 2	7	109	34	42	76	12.7
Buffalo R.	June 20	39	69	36	38	74	12.3
Little Wood R.	July 10	8	149	39	32	71	11.8
MF Payette R.	June 25	24	27	35	23	58	9.7
Big Smoky Cr.	July 21	18	95	28	23	51	8.5
M.F. Boise R.	July 15	32	-	28	20	48	8.0
Coeur d'Alene R.	July 16	36	43	19	26	45	7.5
Totals				918	931	1,849	17.1

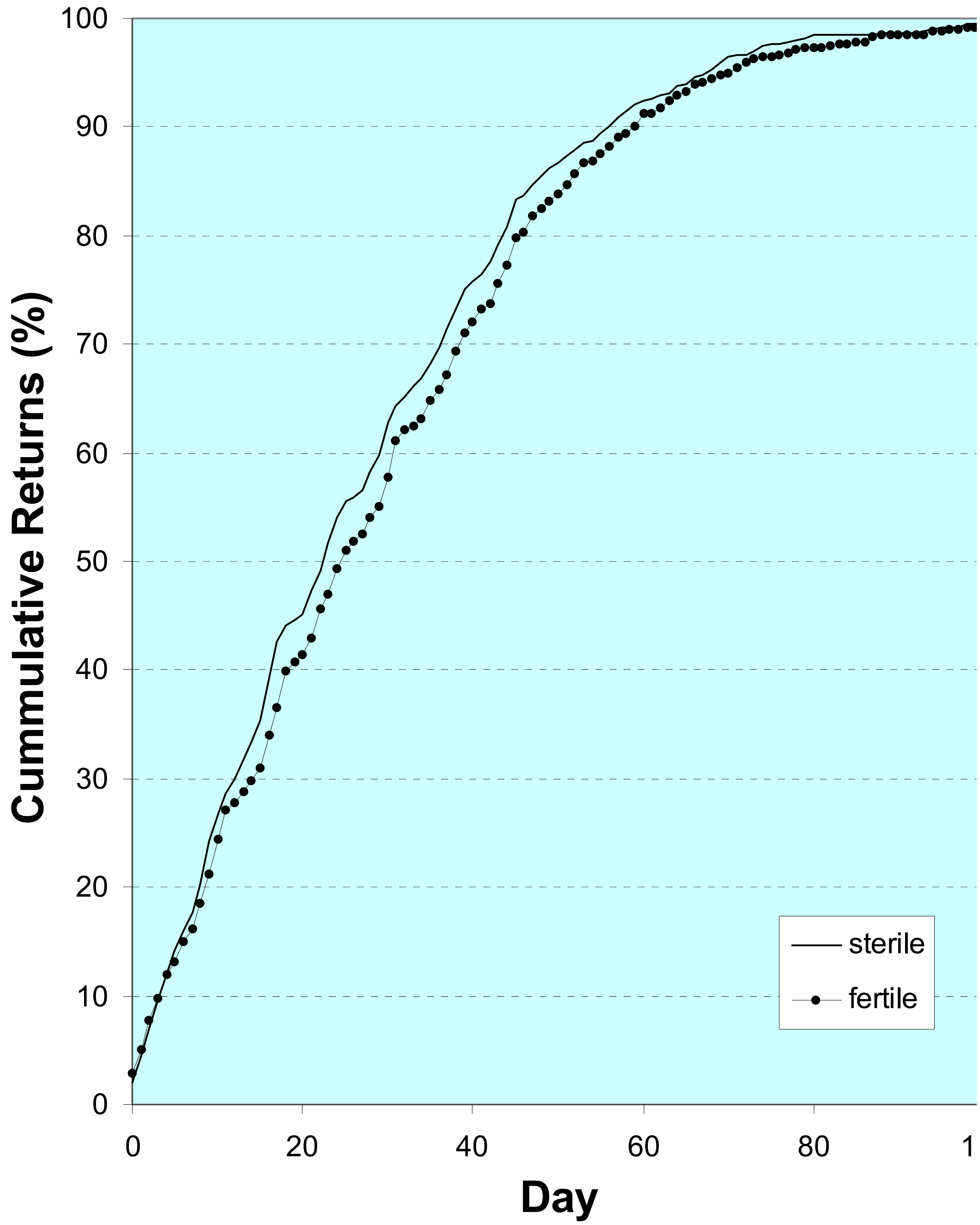

Figure 6. Timing of returns for sterile and fertile catchable rainbow trout planted in 18 Idaho streams.

Table 3. Triploid induction results for Hayspur strain rainbow trout. The duration of heat shock was the same for all treatments at 20 min. Triploid induction results for the 27°C treatments were not available at the time this report was completed.

	Treatment		Spawning characteristics		Survival (%)		Survival (% of control)		% Triploid
Replicate	Temp (°C)	MAF	♀,♂	Age	Eye	Hatch	Eye	Hatch	
1 Nov. 20, 1998	26	15	10,10	2+	33	24	57 [a]	-	100
	26	20			63	40			93
	28	15			27	18			98
	28	20			46	21			95
2 Dec. 16, 1998	26	10	10,10	3+	61	38	119	100	100
	26	15			55	43	104	119	100
	26	20			59	46	106	119	100
	28	10			40	20	78	53	95
	28	15			43	23	81	63	91
	28	20			44	24	80	61	97
3 Jan. 30, 1998	26	15	4,4	4-7	80	59	98	90	fish were not reared
	26	20			81	59	102	87	
	26	25			77	57	95	87	
	27	20			78	55	98	84	
	27	25			75	51	92	76	

[a] Survival estimated from production eggs.

DISCUSSION

Sterile Stream Catchables

Numerous researchers have documented a range of genetic impacts on wild fish from introduced hatchery fish. Effects have ranged from no detectable introgression (Krueger and Menzel 1979; Wishard et al. 1984; Jones et al. 1996) to virtually complete replacement of locally-adapted stocks by hybrid swarms (Gyllentsen et al. 1985). Fishery managers today more clearly recognize potential genetic risks than in the past, but still attempt to balance wild fish conservation with public and political pressures to provide consumptive angling opportunity. If sterile trout can meet fishery goals as well as normal fertile trout, they will be a valuable tool with which managers can address both issues. Our results provide strong evidence that in stream fisheries, sterile triploid rainbow trout can provide put-and-take harvest opportunity comparable to fertile hatchery fish.

Although our paired stocking design with 18 streams had high statistical power, there are several potential study limitations. Mean size at stocking for sterile fish was statistically greater (*p* <0.05) than for control fish. Because return-to-the-creel in streams is sometimes positively correlated with size at stocking (Mullan 1956, Walters et al. 1997), our results could have been biased in favor of sterile fish returns. However, statistical difference does not necessarily equate to biological significance (Gold 1969; Steidl et al. 1997). The difference in mean total length between sterile and control fish in our study (16 mm) was smaller than typically documented as affecting returns in past studies. For example, Mullan (1956) documented different return rates among 2 in (51 mm) size groups of various species of hatchery trout. We are assuming the smaller difference in mean size at stocking in our experiment did not influence our study results.

In addition, our sole evaluation criterium was relative return-to-the-creel. We did not assess long-term survival, growth, or behavioral differences between sterile and control groups. Timing of returns suggests survival and catchability were similar. In both groups, over 90% of returns occurred within 57 d of stocking, with very few returns thereafter. Because the rainbow trout used in this experiment were highly domesticated, we did not expect significant long-term or overwinter survival in our study streams (Shetter and Hazzard 1941; Miller 1958; Reimers 1963; Bachman 1984). Behavioral differences, if they occur, could mean sterile fish could have unexpected interactions with wild fish. We suggest future evaluations monitor long-term survival and behavioral differences between sterile and control groups to more clearly describe potential interactions with wild fish.

Assuming our study results are accurate and replicable, sterile salmonids may have utility in a variety of stream fisheries nationwide. For example, Morgan and Danzman (1997) noted widespread introgression of wild brook trout stocks from hatchery introductions in eastern United States of America streams. Several authors have discussed the deleterious effects of continued rainbow trout stocking on rare stocks of Gila trout, Apache trout, and Rio Grande cutthroat trout (Dowling and Childs 1992; Stumpff and Cowley 1997), with the former authors calling for studies to identify barriers to gene exchange with introduced rainbow trout. Use of sterile fish in stocking programs would seem to have potential in these situations.

Increased production cost is a consideration that could affect applicability of sterile fish in stocking programs. In this experiment, costs for triploid rainbow trout eggs were 2.3 times the cost of normal eggs, and hatch and survival to hatch for triploids was lower. Most of the expense of rearing catchable-sized trout is feed costs rather than egg costs; however, and our estimated total rearing cost for triploid catchables was only about 15% higher than for control catchables. If triploid rainbow trout were to comprise a significant portion of hatchery production, differences in rearing costs would need to be accounted for by either increasing hatchery budgets or by slightly reducing total production and stocking rates. Fishery managers and policy makers must assess the tradeoffs of higher stocking costs, or decreased stocking rates, versus the ability to afford genetic protection to wild fish.

Given the history of genetic impacts from hatchery fish introductions and the likelihood public demand for consumptive stream fisheries will continue, fishery managers must find innovative ways to meet competing agency mandates. Sterile hatchery trout represent a potentially valuable tool with which managers can help balance public demand with sound conservation strategies for wild trout. Additional research and management evaluation is needed to explore this potential.

Sterile Fingerlings in Lakes and Reservoirs

Preliminary results from 1997 data collections show similar survival and growth for age-1 sterile and control fish stocked in seven Idaho reservoirs. Our results, however, are based on very low sample sizes, and additional data from older age classes must be collected before any final conclusions can be made. Also, we assumed mark retention was similar for red and green grit mark dye. If retention was not similar, our results could be biased in favor of sterile or control fish. Nielson (1990), however, observed similar retention of green and red grit dye colors during a 12-year study. Nielson (1990) also reported after six years, mark retention was 86% for grit-dyed fingerlings.

Our preliminary reservoir investigations contradict findings from Brock et al. (1994). In Alaska, survival to age-1 from fingerling plants was significantly lower for sterile fish. Poor survival, however, declined as fish aged; and in one of five lakes, sterile fish outperformed the control group (Brock et al. 1994). Additionally, Parkinson and Tsumura (1988) found sterile kokanee survival was lower during the first few years after release, but catches of sterile fish exceeded controls when older age classes were compared. The authors concluded the increased proportion of older kokanee (age-2 and older) may offset the higher mortality of younger kokanee.

Triploid Induction

Based on our literature review and successful induction trials, Hayspur broodstock should be treated with a temperature shock of 26°C for 20 min. Pooled data from five 26°C treatments resulted in an average induction rate of 99%, with four of five treatments being 100% triploid. In addition to excellent induction rates, survival to hatch in the 26°C heat shock treatments averaged 100% of control groups. Time after fertilization does not appear to be as important as temperature, but should not exceed 25 min after fertilization.

We are continuing to rear about 30 tetraploid rainbow trout at Hayspur Fish Hatchery and anticipate we will spawn those fish during the winter of 1998-1999. The development of a tetraploid broodstock, however, does not appear to be as important, given the recent success and ease with sterilizing rainbow trout using temperature shock.

RECOMMENDATIONS

1. IDFG should begin stocking sterile catchables in streams scheduled for rainbow trout stocking and where introgression with wild trout populations is a concern.

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APPENDICES

Appendix C. Literature review and summary table of triploid induction in rainbow trout.

TRIPLOID INDUCTION FOR RAINBOW TROUT

Techniques for inducing triploidy in rainbow trout *Oncorhynchus mykiss* have been actively studied since the early 1980s (Chourrout 1980; Thorgaard et al. 1981; Chourrout 1984; Shelton et al. 1986). The most common treatments subject fertilized eggs to heat, pressure, or chemical shock. This causes retention of the second polar body of the egg and results in an embryo with two sets of maternal and one set of paternal chromosomes (Johnstone 1985). This retention of the second polar body occasionally occurs naturally and results in triploid fish (Gold and Avise 1976; Thorgaard and Gall 1979).

Regardless of treatment type (heat, pressure, or chemical), timing, duration, and intensity of shock are all important factors in triploid induction (Thorgaard 1983). These factors will vary according to many variables, including fish stock (Streisinger et al. 1981), ambient water temperature (Feist et al. 1996), and egg maturity (Refstie et al. 1982).

Pressure shock has been a successful method for inducing triploidy in rainbow trout (Chourrout 1984; Chourrout et al. 1986; Guoxiong et al. 1989; Feist et al. 1996). The most common pressure treatments range from 6,000 psi to 10,000 psi at 10 min to 40 min after fertilization (MAF) for durations of 3 min to 6 min. The literature we reviewed showed induction rates of 80% to 100% triploidy and triploid yields ranging from 5.2% to 97.2% for pressure shocks. Triploid yield is the product of triploid induction rate and survival rate to hatch. Despite the successful trials, pressure shock requires expensive equipment and relatively few eggs can be treated at one time.

Treating eggs and fry with chemicals has also been a method used for sterilizing rainbow trout (Valentine et al. 1994). The induction process can be completed by supplementing the diet with steroids and/or submersing fry in chemical solutions. However, due to federal restrictions and lengthy application processes, the use of chemical treatment has been limited. Given the permit issues and the lack of replication using chemical treatments, we concluded chemical shock was not the best option for the Idaho Department of Fish and Game triploid induction program.

Heat shock was the most common method used for triploid induction (Chourrout 1980; Thorgaard et al. 1981; Chourrout and Quillet 1982; Guo et al. 1990; Goryczko et al. 1992; Feist et al. 1996). Our literature review showed treatments ranging from 24°C to 36°C, 0 MAF to 70 MAF, and treatment durations of 1 min to 25 min (Appendix C, Table C-1). The lower temperature treatments (24°C and 25°C) produced lower triploid rates (Solar et al. 1984; Idaho Department of Fish and Game [IDFG] 1997, unpublished data) and higher temperatures appeared to reduce survival and triploid induction rates (Berg et al. 1993; Solar et al. 1984; Thorgaard et al. 1981; Dillon and Alexander 1997). It is also important to note the duration of treatment and temperature are inversely proportional (Appendix C, Table C-1). In summary, heat shock is relatively simple, equipment costs are minimal, and induction rates can be high.

Appendix C. Continued.

Table C-1. Summary of triploid induction for rainbow trout.

	Treatment							
	Heat			Pressure			Triploid	
		Duration	Temperature	(psi)	Survival to Hatch		Induction	
Author(s)	**MAF**	**(min)**	**(°C)**	**(x 1,000)**	**Control**	**Triploid**	**Rate**	**Performance of Triploids**
Berg et al. 1993	10	1	36		87	45	63	lower hatch, lower survival to stocking, and smaller size at stocking
	10	1	36		98	77	82	
Bye and Lincoln 1986	40	10	28			<40	>90	survival was greater than 20% to 40% at swim-up
Chourrout 1980	0-70	10	27-30				50	
Chourrout and Quillet 1982	25	20	26				100	survival to swim-up was equal to control
Chourrout 1984	10	8		6		52	100	
	40	7		7		35	100	
	40	5		7		60	100	
	40	3		7		85	100	
Chourrout et al. 1986	25	20	26		67	47	100	slightly lower survival and growth than diploids
	40	4		7	67	47	100	
Dillon and Alexander 1997 (IDFG 97-35)	10	10	28.5		62	13	70	rainbow trout X cutthroat trout hybrids
Dillon and Alexander 1997 (IDFG 97-35)	10	10	29.5		62	6	35	rainbow trout X cutthroat trout hybrids

Table C-1. Continued.

	Treatment							
	Heat			Pressure			Triploid	
		Duration	Temperature	(psi)	Survival to Hatch		Induction	
Author(s)	MAF	(min)	(°C)	(x 1,000)	Control	Triploid	Rate	Performance of Triploids
Dillon and Alexander 1997 (IDFG 97-35)	10	20	25				12	rainbow trout X cutthroat trout hybrids
	10	20	26				14	rainbow trout X cutthroat trout hybrids
	10	20	27				70	rainbow trout X cutthroat trout hybrids
Feist et al. 1996	10	10	29					heat shock should be at least 15°C warmer than ambient water temperature
	10	20	26					
Goryczko et al. 1992	40	10	28				100	triploid hybrids had faster growth and lower survival than diploid rainbow trout
Guo et al. 1990	30	17	27				93	greater mortality in the first 100 days post-fertilization and lower mortality from 100 to 233 days post-fertilization
Guoxiong et al. 1989	25	20	26			49	100	
	25	10	26			72	70	
	25	6		10		59	85	
Lincoln and Scott 1983	0-45	10-15	27-28				100	
Meyers and Hershberger 1991	25	25	27.2		69	65	98	greater mortality and susceptibility to pathogens

Appendix C. Continued

Table C-1. Continued.

Author(s)	Treatment: Heat MAF	Heat Duration (min)	Heat Temperature (°C)	Pressure (psi) (x 1,000)	Survival to Hatch Control	Survival to Hatch Triploid	Triploid Induction Rate	Performance of Triploids
Solar et al. 1984	1	10	24		86	47	18	more deformities, greater mortality, and slower growth
	40	10	24		86	93	30	
	1	10	26		86	65	83	
	40	10	26		86	57	90	
	1	10	28		86	69	83	
	40	10	28		86	50	100	
	1	10	30		86	55	67	
	40	10	30		86	0	0	
Thorgaard et al. 1981	10	1	36		58	34	45	
Thorgaard 1986	10	10	29		84	f48	96	
Vander Haegen 1997	20	20	26				88	
	40	10	28				80	
	20	20	26				100	
	40	10	28				68	
	20	20	26				100	
	40	10	28				100	
IDFG unpublished data (11/96 Hayspur)	12	20	26				74	
	14	20	26				88	
IDFG unpublished data (11/20/97 Hayspur)	15	20	26			24	100	
	15	20	28			18	98	
	20	20	26			40	93	
	20	20	28			21	95	

Appendix C. Continued
Table C-1. Continued.

Author(s)	Treatment				Survival to Hatch		Triploid Induction Rate	Performance of Triploids
	Heat			Pressure (psi) (x 1,000)				
	MAF	Duration (min)	Temperature (°C)		Control	Triploid		
IDFG unpublished data (12/16/97 Hayspur)	10	20	26		38	38	100	
	15	20	26		36	43	100	
	20	20	26		39	46	100	
	10	20	28		38	20	95	
	15	20	28		36	23	91	
	20	20	28		39	24	97	

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Appendix C. Continued.

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